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ACTS Experiments Program

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ACTS EXPERIMENTS PROGRAM

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ABSTRACT

This paper presents an overview of the ACTS Experiments Program. ACTS is being developed and will flight test the advanced technologies associated with: a Ka-band multibeam antenna, onboard signal processing and switching as well as laser communications. A nominal 3 yr experiments program is planned. Through the experiments program, the capabilities of the ACTS system will be made available to U.S. industry, university and government experimenters to test, prove the feasibility and evaluate the key ACTS system technologies. Communication modes of operation using the baseband processor and microwave switch matrix are presented, along with the antenna coverage pattern. Potential experiment categories are also presented and briefly discussed. An overall schedule of activities associated with the experiments program is outlined. Results of the ACTS Experiments Program will provide information vital to successful industry implementation of ACTS technology in future operational systems.

ACTS PROGRAM

The ACTS is a key element in the goal of NASA's Advanced Communications Program to develop high-risk, advanced communications technology usable in multiple frequency bands to support our nation's future communications needs. Realization of this goal will enable growth in capacity and effective utilization of the frequency spectrum and maintain United States preeminence in satellite communications.

To accommodate the projected increases in telecommunications demand for the 1990's, technology innovations which permit more effective frequency spectrum use and cost-effective customer premises satellite earth terminals and networks are needed.

Using multiple spot beams and advanced onboard switching and processing systems, ACTS will pioneer new vistas in communication satellite technology. These antenna and switching systems technologies, which are generic for existing (Ku) as well as new (Ka) frequency bands, require flight experimentation as an essential part of this technology development process.

The NASA ACTS program sponsors the development and flight test of high-risk, advanced communications satellite technology. Key technologies to be validated as part of the ACTS program include: MULTIBEAM ANTENNA - a rapidly reconfigurable hopping beam antenna to serve users with optimum efficiency; BASEBAND PROCESSOR - a high-speed digital switchboard in the sky for efficient use of time and transponder capacity via individual message routing; MICROWAVE SWITCH MATRIX - dynamic reconfigurable switch to handle high-volume traffic via point-to-point communications; RAIN FADE COMPENSATION - techniques such as forward error correction, power control and use of diversity ground terminals to automatically adjust to uplink and downlink fades; KA-BAND COMPONENTS - development of both flight and ground terminal hardware at 20 and 30 GHz; and LASERCOM COMMUNICATIONS - development of laser communications technology for intersatellite link applications.

NASA Lewis Research Center in Cleveland, Ohio, has been assigned overall project management responsibility for the ACTS Project. ACTS is being developed for launch from the shuttle.

RCA's Astro-Electronics Group, Princeton, New Jersey, leads the contractor team developing ACTS. Major members of this team under RCA are TRW Electronics Group, Space Communications Division, Redondo Beach, California; Communications Satellite Corporation (COMSAT), Washington, DC; and Motorola Inc., Aerospace Electronics Office, Scottsdale, Arizona.

ACTS EXPERIMENTS PROGRAM

A major goal of the NASA ACTS program is to obtain the widest possible involvement of all United States institutions and the telecommunications user community in the evaluation and testing of this advanced technology. This goal will be accomplished through the ACTS Experiments Program. The ACTS Experiments Program will make available the capabilities of the ACTS system (flight and ground segments) for experimentation to the public and private sectors of the United States (industry, universities and government). This will allow experimenters to test, prove the feasibility and evaluate the key ACTS system technologies. The flight and ground segments are being developed to permit the required experiments and data analysis to be conducted.

A nominal 3-yr period of experimentation is planned after launch and a subsequent period of on-orbit checkout.

ACTS SYSTEM OVERVIEW

The ACTS system (Fig. 1) is made up of a flight segment and a ground segment. The flight segment consists of a Multibeam Communications Package (MCP) and the spacecraft bus. The ACTS flight segment is shown in Fig. 2. ACTS will be located in geosynchronous orbit at 100° west longitude. In orbit ACTS will weigh approximately 2860 lb and will measure 46.5 ft from tip to tip along the solar arrays and 30 ft from one antenna to another.

Separate Ka-band (30/20 GHz) antennas, each with horizontal and vertical polarization feed systems, are provided for transmit and receive signals. The offset Cassegrain antenna system provides hopping spot beams for independent and simultaneous coverage of an east and west scan sector (see Fig. 1), with additional spot beams for isolated location coverage outside of each sector and three fixed spot beams. Within the beams, access will be by demand assigned multiple access (DAMA) utilizing Time Division Multiple Access (TDMA). The MCP provides the means for receiving, processing, switching, amplifying and transmitting signals carrying high-speed digital communications traffic.

A major feature of the ACTS system is the use of dynamic rain fade compensation. The ACTS flight system will incorporate three beacons for real time fade measurements; two in the downlink frequency band and one in the uplink frequency band. Signals from all three beacons will be transmitted via a full CONUS coverage antenna. The downlink frequency beacons at 20.185 GHz (vertical polarization) and 20.195 GHz (horizontal polarization) will be used for telemetry, ranging and power monitoring (fade control) as well as for propagation studies. The uplink frequency beacon at 27.505 GHz (vertical polarization) will be used for power monitoring for the ACTS communication system and for propagation studies.

In addition to the rf communications package, ACTS will include a laser optical communication package provided by the Air Force. The laser communications package is being developed for the Air Force by MIT Lincoln Laboratory. NASA's Goddard Space Flight Center (GSFC) will also provide hardward for integration by Lincoln Laboratories into this laser communications package. The laser communications experiments will involve a series of tests intended to verify the engineering parameters, operational performance and technical maturity of both heterodyne (MIT/LL) and direct detection (NASA GSFC) high-rate data transmission experiments. Tests of these optical communications concepts will be a major step in developing crosslink systems to operate between satellites.

Initial testing with the ACTS laser communication system will be performed using a special purpose ground station as a substitute for another satellite. Although atmospheric effects on an optical signal propagating between a ground station and the ACTS degrade link performance below that which would be expected in a space-to-space optical communication link, the ground sites permit a simpler and less expensive initial verification of intersatellite optical communication technology. The ground station for the heterodyne optical communication experiments will use technology similar to that which could be used in a second crosslink package. The ground stations for the direct detection experiments will be special optical sites operated by NASA GSFC. Follow-up demonstrations of a complete heterodyne optical intersatellite communication crosslink could use the ACTS experiment package in combination with a heterodyne receiver and transmitter aboard a low-earth-orbit (LEO) spacecraft. Similarly, a direct detection package aboard a LEO spacecraft could be used to demonstrate a direct detection crosslink to the ACTS optical communication package.

The ACTS ground segment comprises the NASA Ground Station and Master Control Station (MCS) co-located at Lewis in Cleveland. Additional ground stations will be provided by ACTS experimenters.

The MCS will provide spacecraft control, network control, experiment management and data recording. All traffic requests will be processed and set up by the MCS. Traffic channel assignments are made on a demand basis under central control of the MCS using inband orderwire channels via the satellite.

RF MODES OF OPERATION

ACTS has two basic rf modes of operation: a Baseband Processor (BBP) mode and a Microwave Switch Matrix (MSM) mode. Both modes operate in a TDMA format with a one millisecond time frame. The BBP mode operates with two simultaneous and independent hopping beams to provide flexible, demand-access communication between small earth stations located directly on customer's premises. Single-hop interconnectivity in a mesh network is provided between all ground terminals within the two hopping scan beams under the control of the MCS. The channel frequency assignment for the two beams are identical (frequency reuse). Bandwidth efficient Serial Minimum Shift Key (SMSK) modulation is used. Uplink bursts are organized in an FDM/TDMA format, while downlinks bursts are Time Division Multiplexed (TDM). The BBP provides on board demodulation, data storage, decoding (if appropriate), routing, encoding (if appropriate), modulation and downlink transmission to the designated area in synchronization with the hopping spot beam dwells.

The BBP routing is switchable on a word-by-word basis, where a word is equivalent to the capacity of a 64 KBPS channel. Fade control is provided by a combination of forward error correction, burst rate reduction and data rate reduction.

The MSM mode employs three active fixed spot beams operating at the same frequency. Dynamic interconnectivity of high volume communications traffic among three fixed beams is accomplished by the switch matrix on a TDMA basis. A 900 MHz (nonlinear) channel is provided whereby the uplink signal is downconverted to IF, routed and upconverted to the downlink frequency on a burst-by-burst basis. Switch configurations are programmable and can be changed by the MCS to optimize traffic flow. Demand assignment is provided by two-way, inband, orderwire channels between the MCS and the traffic terminals. Fade compensation is provided by output power control independently on both the uplink and downlink as well as employing ground station diversity.

Although the normal MSM mode is SS-TDMA, the switch and the multibeam antenna provide the flexibility to freeze the switch to provide three wideband, spot-to-spot Ka-band communications channels in a "bent pipe" configuration for lower-rate carriers as well as a limited number of multiple carriers per transponder.

ACTS MULTIBEAM ANTENNA COVERAGE

Coverage of the ACTS multibeam antenna for the Continental United States is shown in Fig. 3. For the BBP mode of operation, two independent orthogonally polarized hopping beams provide simultaneous coverage for both the uplinks and downlinks. The hopping beams (designated East and West) each provide coverage to: (1) a contiguous area in the Northeast (different for each beam) and (2) a series of isolated spot regions each with a beamwidth of approximately 0.3°. A total of 13 spot regions is divided between the two beams. In addition, ACTS will also contain a separate lower gain, 1 m diameter, steerable antenna capable of being pointed anywhere within the hemisphere of ACTS's field of view. This steerable antenna has a beamwidth of approximately 1° at 20 GHz. It will function as one of the isolated spot beams associated with the West beam. This steerable antenna will provide coverage for Alaska and Hawaii as well as for tracking the shuttle or a spacecraft in low-earth orbit.

In the MSM mode, three active, independent beams are employed. ACTS has three fixed beam spots pointed at Cleveland, Atlanta and Tampa regions. In this mode of operation, it is also possible to "stop" either or both the East and West hopping beams at any location within their respective beam coverage patterns and use these stopped beams in place of either or both Atlanta and Tampa beams.

The ground coverage patterns provided by the ACTS Multibeam and steerable antennas provide a large measure of flexibility for accommodating and interconnecting experimenters in various network configurations.

ACTS GROUND TERMINALS

Table I highlights the characteristics of typical ACTS ground terminals capable of operating in the BBP or MSM modes. Experimenters will be able to interchange components or subsystems, choosing antenna size and uplink power to match their needs. Rain fade compensation can be implemented either manually or automatically.

In the BBP mode, the clear weather uplink burst rates will be either 27.5 and 110 MSPS, where as in the case of rain degradation the burst rates will be coded and reduced to 13.75 and 55 MSPS respectively. The 27.5 MSPS burst rate channels will occupy the same

spectral bandwidth as the 110 MSPS channel and will be frequency division multiplexed on the uplink. The 1-msec TDMA frame can dynamically accommodate various combinations of both uncoded and coded 27.5 and 110 MSPS burst rates in different time slots within the frame. The downlink beams use single-carrier Time Division Multiplex (TDM) transmission at an uncoded burst rate of 110 MSPS and a coded burst rate of 55 MSPS. The BBP throughput capacity is planned in multiples of incremental standard data rate of 64 KBPS, called an Equivalent Voice Circuit (EVC). Different voice, video and data traffic transmission rates can be accommodated by aggregating these basic 64 KBPS channels.

It should be noted that currently, very small aperture terminals (VSAT) using non-processing satellites are gaining great acceptance as a cost-effective solution for bursty two-way data, while bypassing the terrestrial network. However, VSAT networks are not competitive for toll-grade voice networking or T-1 capacity that is needed in many business applications. The ACTS technology achieves this toll-grade network voice and T-1 capacity, as well as bursty data, while still employing VSAT type 1.8-m stations (MICRO-1).

In the MSM Dynamic mode, a ground terminal with a 220 MSPS capacity is being planned for Satellite Switched-TDMA operation. In the MSM Static mode, the 900 MHz wideband channels can support lower-rate carriers in a bent-pipe mode.

The versatility of the ACTS ground terminals in both physical size, rf power and traffic capacity should meet the experimenters' needs without undue complexity or expense.

EXPERIMENT CATEGORIES

In order to meet the goals of the ACTS Experiments Program, experiments are needed to: (1) verify the on-orbit performance of the advanced technology components of the ACTS flight system, including both rf and optical; (2) verify the feasibility of the system concepts which provide spectrum conservative communications services; (3) demonstrate and evaluate the system networking aspects of the switching and processing technology; (4) characterize the transmission medium, along with techniques to combat fade attenuation; (5) evaluate the basic capabilities and performance of various types of low and high data rate TDMA ground terminals; (6) demonstrate the commercial viability and market acceptability of both existing and new telecommunications, voice, video and data services.

A number of representative experiment subcategories have been identified for the ACTS Experiment Program. These experiment subcategories and their relationship to the technology to be developed within the ACTS program are briefly described in the following section. It should be noted that this experiments subcategory list is not meant to be exhaustive. Experiments within the scope of the ACTS program but not identified in this subcategory listing are certainly invited.

Flight System Technology Experiments

Experiments to evaluate the performance and reliability of the specific multibeam communications subsystems which are included on board the ACTS flight system, such as the multiple beam antennas, the baseband processor, matrix switch, low noise receivers and traveling wave tube transmitters.

Ground System Technology Experiments

Experiments that evaluate the performance of the ground stations.

Network Control

Experiments to evaluate the performance and efficiency of a Time Division Multiple Access (TDMA) and Demand Assigned Multiple Access (DAMA) System and to evaluate network access and control as a function of signal quality and time. Experiments to evaluate the performance of various communications protocols.

Acquisition, Tracking, and Synchronization

Experiments that evaluate acquisition, tracking and Time Division Multiple Access (TDMA) synchronization and timing considering ACTS flight station-keeping accuracy and antenna-pointing accuracy.

Transmission Impairments

Experiments that evaluate system impairments, particularly interference as a function of beam separation.

Enhancement of Link Availability/Rain Compensation Techniques.

Experiments to evaluate 30/20 GHz availability and performance improvements with such techniques as earth stations with spatial diversity, adaptive power control and forward error correction.

Propagation Experiments

Experiments to develop propagation statistics to characterize propagation impairments such as fading, scintillation and depolarization for all CONUS rain zones.

Experiments to evaluate quantitatively the impact of such propagation impairments on the ACTS system performance.

End-to-End System Experiments

Experiments to develop voice, video and data applications for use with advanced communications satellite systems.

Lasercom Experiments

Optical experiments to demonstrate the performance of both heterodyne and direct detection laser high-rate data transmission links between synchronous orbit and optical terminals located either on earth, in low-earth orbit or at other longitudes in synchronous orbit.

NASA recognizes that it may be of interest to some organizations experimenting with ACTS to keep certain information regarding the conduct of their experiment or its analyzed results proprietary. Public disclosure of an ACTS experiment and its analyzed results is certainly encouraged. Legal, cooperative agreements protecting proprietary information, however, can be entered between NASA and those organizations so desiring, on an individual basis. Such an agreement will protect the proprietary aspects of an experiment from public dissemination, while still providing NASA with an evaluation and verification of the performance of the ACTS spacecraft.

EXPERIMENT APPROACH

The schedule of activities for the ACTS Experiments Program is shown Fig. 4. A Notice of Intent for Experiments (NOI) was issued by NASA Headquarters in March 1983 to: (1) identify those organizations interested in experimenting with the Advanced Communications Technology Satellite and (2) to determine insofar as possible what the experiment characteristics and requirements would be. The NOI solicited an expression of intent to conduct an experiment and a preliminary description of the proposed experiment. NASA will strive to accommodate all United States experiments that are technically and scientifically relevant to the basic objectives of the ACTS program.

To facilitate the timely development of the multibeam antenna, it was necessary to specify the antenna beam locations in mid-1985. Selected antenna ground coverage locations were based, among other considerations, on the initial experimenter responses to the NOI.

A more formal commitment to the experiments program will be solicited through an Experiments Opportunity Notice (EON) planned for issue in 1987.

Experimenters are expected to include personnel from Lewis, other NASA centers, United States industries, universities and other government agencies.

Responsibilities of both NASA and the experimenters are outlined in Table II. NASA will furnish the ACTS spacecraft, the NASA Ground Station (NGS) and Master Control Station (MCS) and access to the ACTS spacecraft at no cost to the experimenter during the planned 3-yr experiments period. Experimenter access to and use of the NGS will also be accommodated on a noninterference basis. NASA will manage the planning, scheduling and operations of all experiments. Data for component performance evaluation for the advanced technology hardware on board the spacecraft, along with pertinent spacecraft/MCS auxiliary correlating data necessary for the various technology and system experiments will be collected and archived in the MCS and distributed to the appropriate investigators.

The experimenters will be responsible for providing the resources required to plan, coordinate, conduct their proposed experiments and to report the analyzed results.

An important element in the development of the experiments program will be the formation of an Experiments Working Group. This group will be composed of all experimenters and will define plans and coordinate ACTS Network/Experiment compatibility. Key activities of this group will be to promote dialogue between experimenters as well as foster the formation of experiment teams where individual experimenters could pool their resources to maximize their experiment capability. This group will also assist NASA in determining experiment networks and the allocation of the various ACTS system resources to and for the various phases of the experiments program.

A NASA Ground Terminal Development team has been formed at Lewis to assist in the procurement of suitable ground terminals for experiments. NASA, in coordination with experimenters, will develop overall ground terminal requirements and system specifications. Designs will stress component modularity to allow experimenters flexibility in configuring their own terminals. This team will act as a procurement agent for government agencies and other interested organizations in an attempt to lower terminal costs by aggregating individual procurements into a group buy. Procurements will be structured

to minimize cost as well as to encourage the maximum number of equipment/terminal manufactures to participate. Ground terminal designs and specification will also be made available to interested experimenters. This team will also assist experimenters with training, site selection, installation, checkout and maintenance of their ground terminals.

After launch and a subsequent period for on-orbit checkout, a nominal 3 yr period of experimentation is planned. It should be noted that a launch date has not been established at this time due to Shuttle manifest uncertainty. The earliest launch date would be May 1990. Figure 5 provides an overview of the major activities and interaction between the NGS/MCS, the ACTS spacecraft and the experimenters ground terminals during this experiments operation period. The MCS will provide Mission, Network and Experiment Operations functions.

EXPERIMENTER RESPONSES

A summary of the experimenter responses to date to the NOI for ACTS Experiments is presented in Table III. Eighty-five (85) organizations have responded, representing a broad cross section of the United States telecommunication industry, universities and government agencies. From these responses, some 122 experiments have been proposed and distributed throughout the various experiment categories presented in Section 7.

SUMMARY

As the ACTS project completes its preliminary design phase, the designs of all major flight and ground segment system and subsystem are nearing completion. Key subsystems are already being implemented in hardware. As the characteristic of these major system elements take shape, more detailed experiment planning is being initiated by NASA.

The ACTS project objectives will be met only when the ACTS system is deployed, tested and evaluated by a broad cross section of United States experimenters. When completed in the 1990s, the ACTS program will have developed a mature, space-qualified base of technology from which industry can draw new communications satellite capabilities. Implementation of this technology in the operational systems of the 1990's and beyond will help ensure continued growth of the U.S. communications satellite industry and enhance its position as a leader in advanced communications satellite technology.

TABLE I. - TYPICAL ACTS GROUND TERMINALS

Satellite routing mode	Type	Antenna diameter, M	Trans-mitter power, W	Capacity	Uplink burst rate, MSPS	Downlink burst rate, MSPS	Access
EVC - 64 KBPS Equivalent voice circuit							
Baseband processor via two hopping beams	Micro-1	1.8	10	1 to 24 EVC	13.75	55	TDMA
	LBR-2	3.0	15	1 to 48 EVC	27.5	110	TDMA
	LBR-1	5.0	15	1 to 96 EVC	110	110	TDMA
MSM - Microwave Switch Matrix							
MSM static (bent pipe) via three stationary beams	Micro-2	0.3-1	1	56 - 512 KBPS	N/A	N/A	FDMA
MSM Dynamic via three stationary beams	HBR	5.0	480	220 MBPS	220	220	TDMA

TABLE II. - EXPERIMENTS PROGRAM RESPONSIBILITIES

NASA provides:

- Spacecraft time during nominal 3-yr experiment period
- Master control station operations
- Experiment program management
- NASA ground station for experimenter use
- Data measurements aboard spacecraft and at master control station

NASA will assist experimenters in:

- Experiments planning
- Purchasing and/or leasing terminals
- Utilizing NASA ground station or other organizations' ground terminals

Experimenter provides:

- Experiment plan
- Resources to conduct experiment
- Experimenter working group support
- Experiment operations
- Analysis of experiment results

TABLE III. - SUMMARY OF NOTICE OF INTENT RESPONSES (AS OF JULY 1986)

85 Organizations responded:	18 Equipment manufacturers
	7 Carriers
	17 Educational institutions
	5 Health organizations
	9 Federal government
	7 NASA centers
	1 State and local government
	3 State telecommunications systems
	6 Nonprofit public service organizations
	4 Telecommunications consulting companies
	8 Other corporate firms
122 Experiments	

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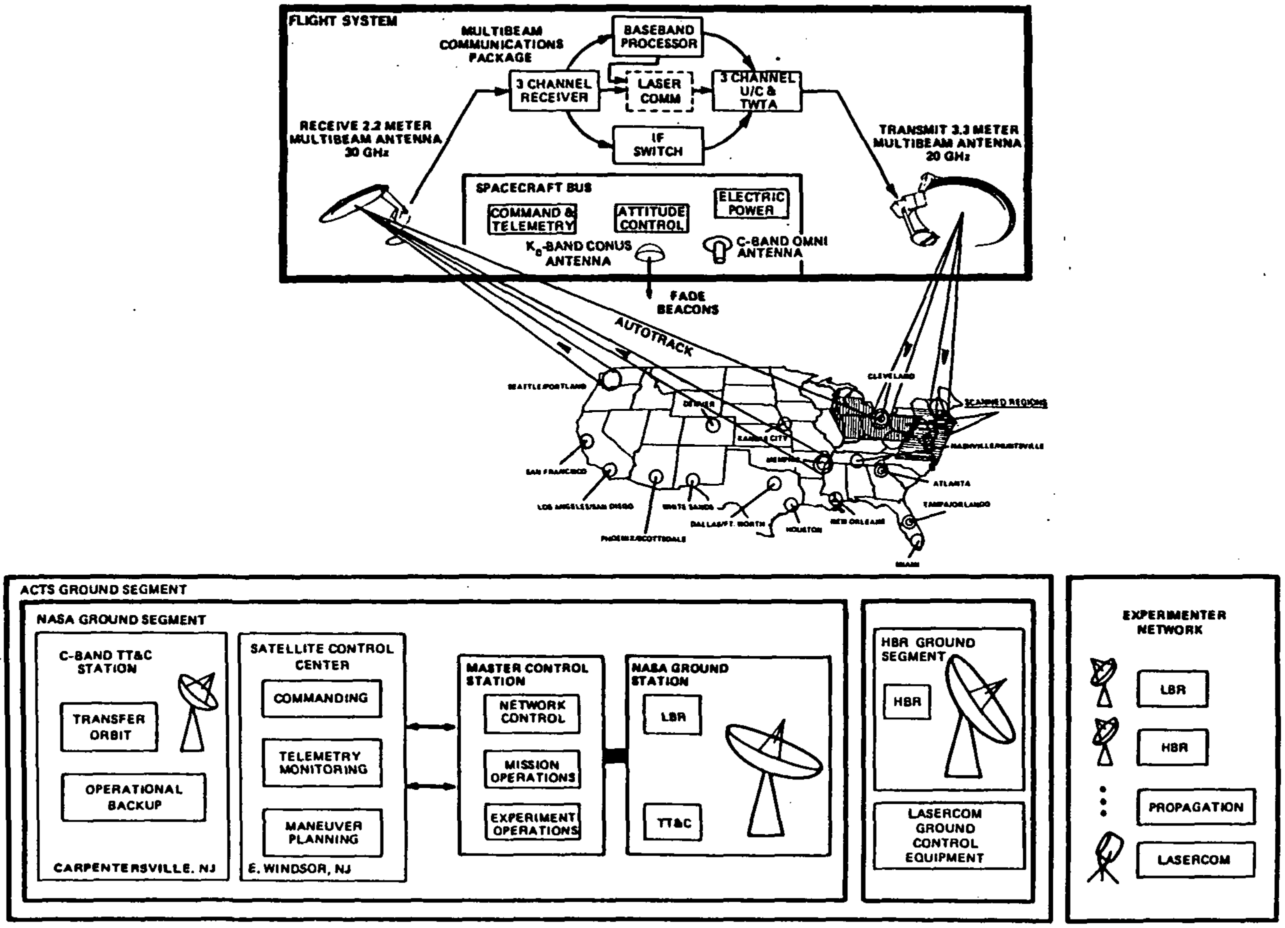


FIGURE 1.- FUNCTIONAL OVERVIEW OF ACTS SYSTEM.

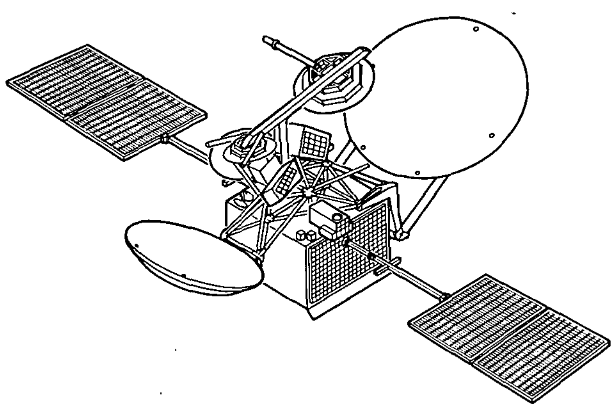


FIGURE 2.- ADVANCED COMMUNICATIONS TECHNOLOGY SATELLITE.

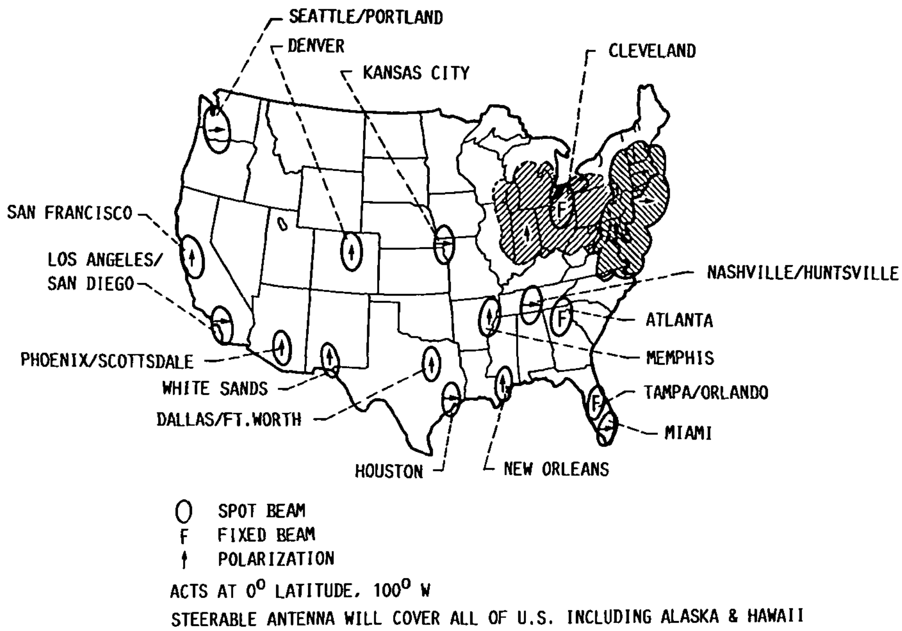
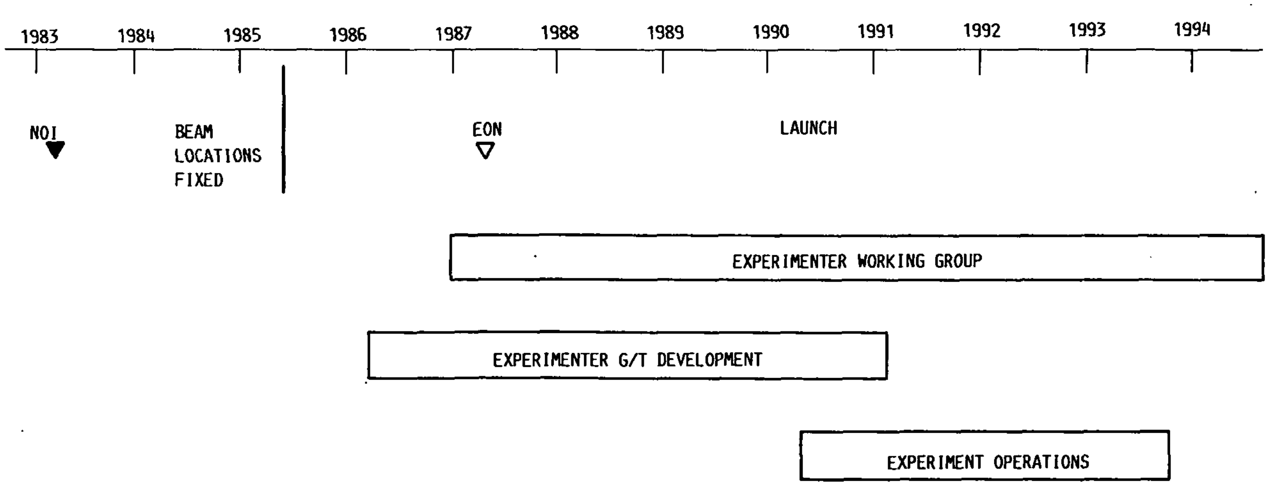


FIGURE 3.- ACTS ANTENNA COVERAGE.



NOI - NOTICE OF INTENT
EON - EXPERIMENT OPPORTUNITY NOTICE

* NOTE: LAUNCH DATE HAS NOT BEEN ESTABLISHED AT THIS TIME DUE TO A SHUTTLE MANIFEST UNCERTAINTY. EARLIEST LAUNCH DATE WOULD MAY, 1990.

FIGURE 4.- ACTS EXPERIMENTS PROGRAM SCHEDULE.

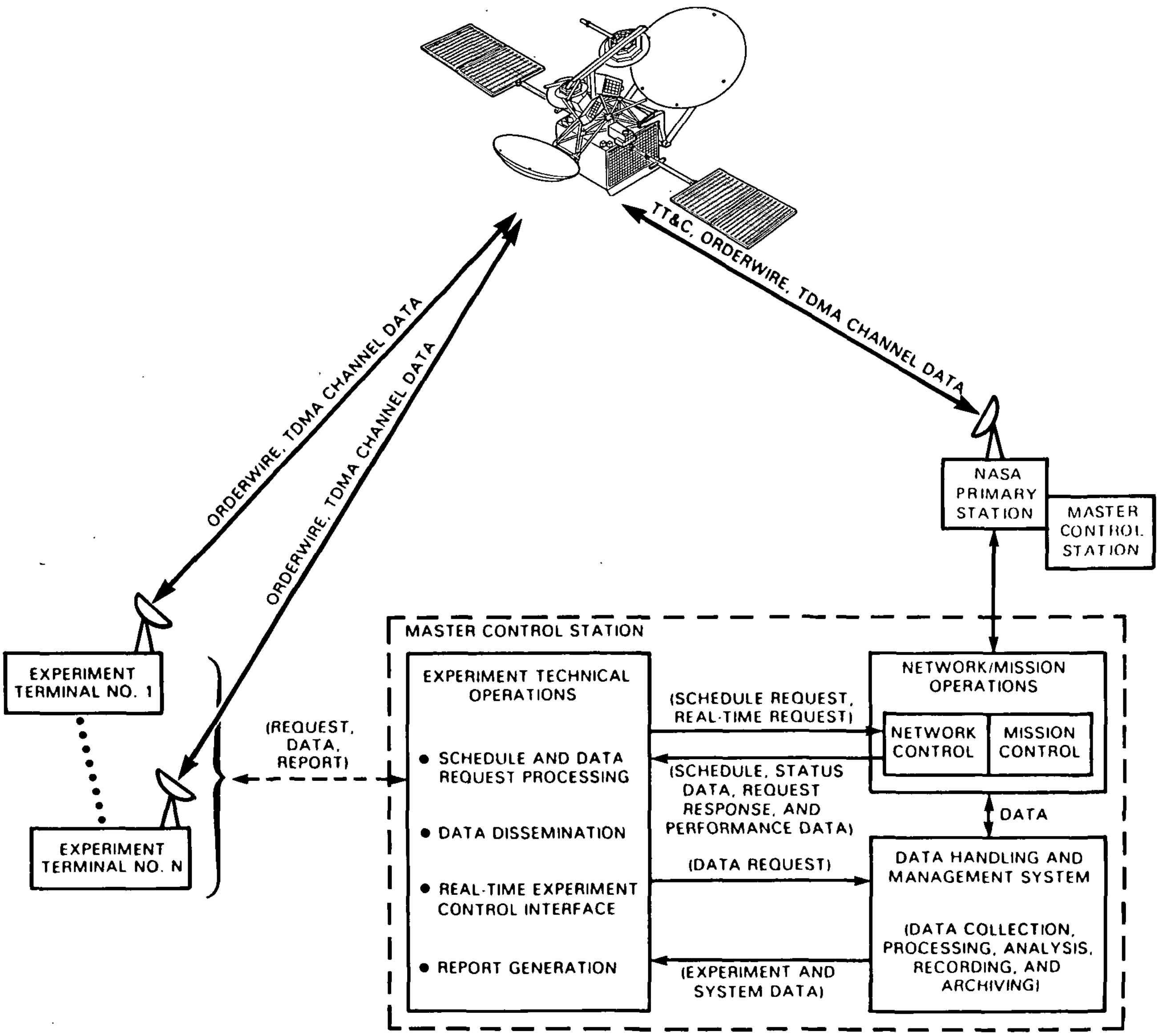


FIGURE 5.- ACTS EXPERIMENT OPERATIONS OVERVIEW.

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